5 ■ Phenomenology and the History of Science

I

"Philosophy . . ., by its very essence, is the science of true beginnings, of origins, the ῥιζώματα πάντων. And the method of a science concerned with the roots of things, the method of a radical science, must itself be radical, and this in every respect."[1] It may be said, not inappropriately, that Husserl, throughout his life, directed his thought to the problems of origin. His earlier writings formulated the approach to the "true beginnings"; he worked all his life discovering, rediscovering, and elucidating these beginnings and the approach to them and finally he adumbrated the aims which should control research in the history of science. It is the purpose of this paper to show the essential connection, as Husserl understood it, between these aims and the "true beginnings."

In attacking "psychologism," Husserl was in fact facing the problem of "history." Any "naturalistic" psychological explanation of human knowledge will inevitably be the history of human

1. "Philosophie als strenge Wissenschaft," *Logos*, i, 340.

First published in *Philosophical Essays in Memory of Edmund Husserl*, ed. Marvin Farber (Cambridge: Harvard University Press, 1940).

development with all its contingencies. For in such an account any "idea" is deduced from earlier experiences out of which that idea "originated."[2] In this view, the explanation of an idea becomes a kind of historical legend, a piece of anthropology. The *Logical Investigations* showed irrefutably that logical, mathematical, and scientific propositions could never be fundamentally and necessarily determined by this sort of explanation.

In order to understand the ultimate validity of logical and mathematical propositions, it is necessary, according to Husserl, to liberate first the problems of origin from an interpretation of mind which confuses mind with nature. "A thing is what it is, and remains in its identity forever: nature is eternal." Nature "appears": it is experienced as something that appears to us through the senses, never "absolutely," rather in different aspects, in different "adumbrations." But the object of mind "appears as itself, through itself," is in itself a "phenomenon," appears as an "absolute" and at the same time "as passing in an absolute flow, appears right now and already fading away, sinking back continuously into what is the past, and this in a way which can be perceived in an immediate intuition." Therefore, whereas a natural thing can be investigated and analyzed by repetition of an experience which is intrinsically the same in so far as the object is the same, a mental object can be re-examined only by reflection, by "retention," in memory, i.e., by a specific change ("modification") in the "manner of givenness." In other words, a natural object, although "temporal," remains constant with respect to our investigation: the object of mind is immersed in "eternal" time, "a time which cannot be measured by any chronometer."[3]

Naturalistic psychology ignores the distinction between the time of mind and the time of nature. As a result, mind itself and all its objects become natural objects, and all problems of origin become problems of origin within natural time. If we liberate these problems from this naturalistic distortion, they become "phenomenological" problems in Husserl's sense of the term.

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2. *Ibid.*, p. 307.
3. *Ibid.*, pp. 312 f. Cf. *Ideen*, pp. 76 ff.

A typical "phenomenological problem" consists in finding the "invariables" within the absolute flow (the "internal temporality") of the mind, in determining the "invariants" which remain unchanged by reason of an essential necessity. This can be accomplished by means of a continuous and arbitrary "variation" of a given "example," a variation that takes place in the "freedom of pure phantasy." "Through such a free and continuously modified variation the necessarily unchangeable, the invariant, comes to the fore, something that is unshakably the same in all the otherness and renewed otherness, the universal and common essence"—the "*eidos*," the "*a priori* form" which corresponds to the example and all its possible variations.[4] But this is only the first step—first in the actual development of Husserl's thought, and first in any phenomenological analysis. The reflection upon this kind of analysis, its implications and its significance leads to a deeper understanding of the nature of a "phenomenological problem." Far from being complete in itself, the finding and facing an "essence" requires a further investigation into its intrinsic "possibility." Whatever we discover as having a definite significance—an essence, its "inflections," its essential characteristics, the compresent "halo," and so forth—has also a "backward reference" to a more original "significant formation." Each "significant formation" *(Sinngebilde)* has its own essential "history of significance" *(Sinnesgeschichte)*, which describes the "genesis" of that mental product. It is the "history" of the "formation" (or "constitution") of that mental product.[5] This curious kind of "history" is a peculiarity of the mind, whose manner of being is nothing but "work" *(Leistung)*, a constructive work, tending to the formation of "units of significance"—an "intentionality at work." All the intended or "intentional" units are thus constructed or "constituted" units, and we can address inquiry to the perfected units as to their "intentional genesis." The discovery of the "intentionality at work" makes us understand the essential and objective possibility of each single significant phenomenon, whether it refers to true being or to mere appearance.[6] Its be-

4. *Logik*, pp. 218 f. Cf. p. 26.
5. *Ibid.*, pp. 184 f.
6. *Ibid.*, p. 226.

ing constructed (or constituted) makes up its "subjectivity." And the last step of the phenomenological analysis is the grasping of the problem of "constitution" in its universality, which in turn leads to a new understanding of phenomenology as the fundamental doctrine of "transcendental subjectivity," the ultimate goal of all possible knowledge, the *sapientia universalis.*[7] Through it is revealed the "constitutive work" of consciousness that determines the "ontic sense" of the world, "consciousness" being understood not as a given "thing" among all other things of the given world, not as the actual thinking of human (or human-like) beings, but as the "intentionality at work" that constitutes any possible thing as a "significant unit," including the significant unit "world" itself. It is an immense and unavoidable task to reveal this working life in its totality, to make everything that "is" intelligible, ultimately out of its constitutive origins.[8] It is this immense task that Husserl sets to his "transcendental phenomenology."

However vague this general outline of Husserl's philosophy might be, it shows, I think, that from the very outset the problem of history has a definite, if not the most important, place in Husserl's mind. The intervention of Dilthey[9] gave a special accentuation to that problem. The essay "Philosophy as a Rigorous Science," which we mentioned at the beginning of this paper, is partly devoted to the praise as well as to the criticism of Dilthey and his history of human thought.[10] It is quite obvious, however, that Husserl in criticizing the attitude of historicism puts it on the same level with psychologism. In fact, the former is but an extension and amplification of the latter. Now, Husserl's radical criticism of psychologism implies anything but a simple opposition between never-changing "abstract" principles and ever-changing "empirical" things. The fact that Husserl's phenomenological descriptions in the *Logical Investigations* were immediately interpreted as psychological descriptions (of a more subtle nature—as was readily conceded—than those which

7. *Ibid.*, p. 4. Cf. Descartes, *Regulae ad directionem ingenii*, Reg. I.
8. *Logik*, p. 216.
9. Cf. the correspondence between Husserl and Dilthey published by G. Misch, *Lebensphilosophie und Phänomenologie* (Leipzig and Berlin, 1930).
10. Cf. especially the note on p. 326.

usually are laid down in psychological textbooks) shows not merely that a great many readers of Husserl were not able to understand his thought, but that there is a definite affinity between psychological and phenomenological research. Husserl himself always pointed out that Hume was the first to see the problem of a transcendental phenomenology, although he misunderstood its true character and therefore failed entirely to solve it. The psychology of mental phenomena must not necessarily differ from their phenomenological analysis as far as the actual description, the wording, is concerned.[11] The real difference can only be found in the fundamentally different attitude of the thinker toward his objects: on the one hand, the psychologist considers them in a "mundane apperception," taking them as existing elements or parts or qualities of the existing world; on the other hand, the phenomenologist deprives these same objects of their "index of existence," performs the "phenomenological reduction" (the "bracketing") and faces them as "pure" phenomena. Thus, the psychological and phenomenological description of logical operations may be identical, although their real significance differs profoundly. More exactly, we have to distinguish between psychological phenomenology and transcendental phenomenology. The first considers the mind as a "natural" object; the second, the mind as the "transcendental subjectivity." In doing so, however, transcendental phenomenology, as the universal theory of "constitution," is primarily concerned with the problems of origin, the problem of true beginnings. It is worth noting that Husserl, in the passage quoted above, uses as an image the (Empedoclean) term ῥιζώματα πάντων, "roots" of all things, rather than the traditional ἀρχή. A "root" is something out of which things grow until they reach their perfect shape. The ἀρχή of a thing—at least in the traditional "classical" sense of the term—is more directly related to that perfect shape, and somehow indirectly to the actual beginning of the growth. The "radical" aspect of phenomenology is more important to Husserl than its perfection. This is the attitude of a true historian. But it is obvious

11. Cf. especially *Logik*, p. 224.

that the phenomenological approach to the true beginnings requires a quite special kind of history. Its name is "intentional history."

II

In order to clarify Husserl's notion of "intentional history," it may be useful to look at the development and the general background of Husserl's philosophy from a different angle. Husserl's earliest philosophic problem was the "logic" of symbolic mathematics.[12] The paramount importance of this problem can be easily grasped, if we think of the role that symbolic mathematics has played in the development of modern science since the end of the sixteenth century. Husserl's logical researches amount in fact to a reproduction and precise understanding of the "formalization" which took place in mathematics (and philosophy) ever since Vieta and Descartes paved the way for modern science. Husserl himself is, of course, well aware of that historical development. He realizes that the discovery of a formal symbolism by Vieta[13] in his establishment of algebra (*ars analytice, logistice speciosa*) is at the basis of modern mathematics as well as modern science. He ascribes to Leibniz the conception of a universal and symbolic science (*mathesis universalis, ars combinatoria*) which is prior to any "material" mathematical discipline and any "material" logic.[14] He does not seem to appreciate, in this connection, the importance of Stevin's algebraic work and, strangely enough, the Cartesian idea of a *mathesis universalis*, based at least partly upon Stevin and leading directly to the corresponding, if modified, Leibnizian concept.[15] He recognizes the close connection between mathematical "idealization" and the idea of an "exact" nature, first conceived in the physics of Galileo. He stresses the fundamental importance of the Cartesian *cogito*, the correct

12. *Philosophie der Arithmetik* (1891). Cf. *Logik*, p. 76.
13. *Logik*, p. 70.
14. *Ibid.*, pp. 70 f. Cf. *Log. Unt.*, I. pp. 219 ff.
15. See Section IV, herein.

understanding of which leads, in his opinion, to his own "transcendental phenomenology." In all that he is the great interpreter of modern thought — he reveals its hidden implications and presuppositions, he follows and judges its essential tendencies. The contingent sequence of mathematical, scientific, or philosophical theories does not concern him: he is not a historian of accidents. But in descending to the "roots of things" he cannot help meeting "history" as one of the basic tendencies of the modern period.

We should not overlook the fact that the development of modern science is closely followed by the development of "historical consciousness." The "new science" of nature has its complement in the *scienza nuova* of history (Vico).[16] Modern history is neither a chronicle of events nor an edifying or moralizing or glorifying report of memorable deeds in the past, but the discovery and the description of man as a specifically historic being, subject to a "development" which transcends any individual life or even the life of peoples or nations. Modern history is not only — as ancient history is — an interpretation and dramatic exposition of "facts," but also an interpretation of the historic "movement" as such. It is, in this respect, the twin brother of mathematical physics. They are both the dominant powers governing our actual life, setting out the horizon of our thinking and determining the scope of our practice. The historicism of recent decades is but an extreme consequence of that general historic trend. We have already characterized historicism as an extension and amplification of psychologism. On the other hand, psychologism, as developed by the English empiricists of the seventeenth and eighteenth centuries, is, in fact, the first attempt to combine the new mathematical and physical sciences (in either their Cartesian or Newtonian aspects) with a "historical" outlook: Locke and Hume try to set forth the "natural history" (Hume) of our concepts upon which our science, our morals, and our beliefs are founded. This holds for the empirical schools of the nineteenth century as well. It is par-

16. For the role of history in the seventeenth-century, v. L. Strauss, *The Political Philosophy of Hobbes, Its Base and Its Genesis* (Oxford, 1936), especially chapter vi.

ticularly true of John Stuart Mill, who found, as he writes, a "considerable approximation" to what he wanted[17] in William Whewell's *History of the Inductive Sciences*.[18] The history of science appears as a kind of prolegomenon to the system of logic, which in turn is considered mainly as an exposition of the methodical and conceptual foundations of science. It is not merely an accident that both J. S. Mill and Spencer wrote autobiographies (not to forget the short autobiography of Hume), nor that Hume is the author of *The History of England*. As to the prolific historical study in all fields of human activity, which makes up most of the scholarly work during the nineteenth century, it is intended, as it were, to fill the gap between the ever more "formalized" scientific approach to the surrounding world and our daily life, entangled, as it is, in a maze of immediate "practical" problems, difficulties, ambitions, and passions. History, in the usual sense of the term, is not a matter-of-course attitude. The origin of history is in itself a non-historical problem. Whatever historical research might be required to solve it, it leads ultimately to a kind of inquiry which is beyond the scope of a historian, whose purpose is to give the "story" of a given "fact." It may, indeed, lead back to the problem of inquiry, the problem of ἱστορία as such,[19] that is, to the very problem underlying Husserl's concept of an "intentional history."

To inquire into an object means, according to Husserl, first to "bracket" its "objectivity" and then to seek for its "constitutive origins," to reproduce its "intentional genesis." Any object, as a "significant" or "intentional" unit, contains the "sedimented history" of its "constitution."[20] That "history," of course, did not take place within "natural time." Yet it can be understood as a "history" because the intentional genesis belongs to the "life of consciousness," and consciousness itself is primarily constituted as an "absolute stream" determined by the "internal temporality." "Internal temporality" is thus the universal eidetic "form" of

17. See his *Autobiography*, ed. J. J. Coss (New York, 1924), p. 145.
18. Cf. the title of his later book: *Philosophy of the Inductive Sciences, Founded upon their History*.
19. Cf. Plato, *Phaedo*, 96a ff.
20. *Logik*, p. 217.

the intentional genesis.[21] In any inner experience of an intentional object, that object is given originally in the mode of immediate "presence"; this immediate "presentation" is followed, of necessity, by a "retention" of the object, in which the object appears in the mode of "just-having-been-experienced"; through all the successive modes of retentional consciousness – that is to say, through a continuous "modification"– the object is constituted as persisting, as one and the same (identical, "invariant") object. But just as there is a "limit" which the continuous modification of the retentional consciousness approaches and beyond which the "prominence" of the object flows away into the general substratum of consciousness,[22] there is the "past history" of the original "presentation" of the object, which is the proper domain of transcendental phenomenology. It is here that the "evidence" experienced in the immediate presentation assumes the character of a transcendental problem of constitution. It is here that the intrinsic "possibility" of the identity of an object is revealed out of its categorial constituents, that the "intentional genesis" leads back to the "constitutive origins," that the "sedimented history" is reactivated into the "intentional history." Moreover, such a transcendental inquiry into an object may reveal the essential necessity of its being subjected to a history in the usual sense of the term. In other words, it may reveal the essential necessity of a historical development within natural time.

This is the case if the object in question is in itself an "ideal formation" like all mathematical and scientific objects. Any science, in the precise sense of the term, has of necessity its own history. It is founded upon the "intentional history" of its ideal objects. The greatest examples to which Husserl himself referred are Euclidean geometry and Galileo's physics.[23] They are explicitly dealt with in two papers worked out in 1935 and 1936[24] and conceived as parts of a comprehensive work on

21. *Ibid.*, p. 279.
22. *Ibid.*, p. 280.
23. *Ibid.*, pp. 215, 257.
24. "Die Krisis der europäischen Wissenschaften und die transcendentale Phänomenologie, Eine Einleitung in die phänomenologische Philosophie," *Philosophia*, vol. I, 1936; "Die Frage nach dem Ursprung der Geometrie als intentional-historisches Problem," published by E. Fink in *Revue internationale de Philosophie*, i, 2.

phenomenological philosophy to which Husserl devoted his last years.[25] The problem which Husserl faced in those papers is precisely the relation between intentional history and actual history. Here again he takes up a task that psychologism could not solve with its own premises but had attacked in its own way. In doing so, Husserl actually confronted the two greatest powers of modern life, mathematical physics and history, and pushed through to their common "root."

III

The article about the "Origin of Geometry" is but a fragment the importance of which lies in the fact that the concepts of history and of tradition, especially that of the tradition of science, are subjected therein to a careful, if incomplete, analysis. An application of this analysis is given in the "Crisis of the European Sciences and Transcendental Phenomenology." We shall begin with the "Origin of Geometry," and try to connect its main problem with Husserl's more fundamental "transcendental" considerations.

We have already seen that any significant formation is constituted as an "invariant" within the absolute stream of consciousness. As an invariant, as identically the same, it seems to transcend any possible time. Its "eternity," however, is but a mode of "eternal" time: its identity is an intentional product of the transcendental subjectivity which is "at work" through all the categorical determinations that constitute a significant unit. This nexus of significance between the "subjectivity at work" and its intentional products (*Leistungsgebilde)* is thus the real problem of historicity taken in its universal and transcendental meaning. That is to say, the problem of historicity is ultimately the problem of philosophy itself.[26] The "intentionality at work" implies historicity (as "the historical *a priori*") which makes intelligible not only the eternity or supertemporality of the ideal significant formations but the possibility of actual history within

25. Cf. the introduction by E. Fink, *loc. cit.*, p. 203.
26. *Loc. cit.*, p. 219.

natural time as well,[27] at least of the historical development and tradition of a science. The "discovery" of geometry, for instance, as a historical event, is dependent upon a world of "things," understood and dealt with according to their "thingness." But thingness as a significant unit bears essential features, quite independently of any scientific approach to them. "Things" have "bodies," have color, weight, hardness or softness, are smooth or rough, have a shape and a size, can be measured, can be in motion or at rest, and so on. These are not merely so-called "empirical data," but characterize the intuitable "essence" of a "thing" as such. Some of those essential features are apt, by an intrinsic necessity of their own, to be made prominent, for instance their shape or their measurability. This prominence is utilized for "practical" purposes, and the practical handling of things may lead to a more or less satisfactory technique. Here again there is the essential possibility of discovering "in" them a set of somehow privileged "shapes" or "figures" which can be more perfectly measured and brought into relation to each other. The actualization of that possibility rests upon the actual handling of such "material"; and finally the "discovery" of geometry as a "science"—however great the change of attitude, the shifting from practical to theoretical purposes might be—is still dependent upon familiarity with that perfected technique.

The actual way leading to the discovery of geometry may have been entirely different from this one, to which Husserl alludes.[28] It is quite possible, even probable, that geometry as a science came into being as a result of arithmetical and musical preoccupations. But even so, that discovery presupposes a characteristically articulated world, presupposes the acquaintance with a definitely shaped and featured "material," presupposes, in short, the experience of "things."

But the discovery of the science of geometry presupposes *also*, on the part of the "first geometer," an "anticipation" *(Vorhabe)* of what comes into being through his "accomplishment" (*gelingende Ausführung*).[29] These notions of "anticipation" and

27. *Ibid.*, p. 225.
28. Cf. pp. 223 f.
29. P. 208.

"accomplishment" are most important for the understanding of Husserl's thought. They provide us with the link between "intentional history" and actual history. They account for the "evidence" of all the "significant formations" belonging to a science such as geometry. For "accomplishment or what is anticipated means evidence to the active subject: herein the product shows itself originally as itself."[30] But since the product, in the case of geometry, is an ideal product, "anticipation" and the corresponding "accomplishment," as "acts" of the subject (the "first geometer"), are founded upon the "work" of transcendental subjectivity: the ideal formations of geometry are products of the "intentionality at work." "Anticipation" and "accomplishment" *translate* into terms of "reality" what actually takes place within the realm of "transcendental subjectivity." On the other hand – and this is the important point – the constitution of those ideal "intentional units" presupposes, of necessity, the whole complex of experiences leading to the situation in which geometry as a science is capable of being "anticipated" *and* "intended."[31] In other words, "*science, especially geometry, as a subjective intentional product, had to have some definite historical beginning,*"[32] i.e., a beginning within the course of actual history. At this definite moment the "original foundation" *(Urstiftung)* of geometry occurred.

Needless to say, this analysis does not refer to any known or even knowable historical event. It only shows the essential connection between geometry as a supertemporal product of the mind and its "creation" in actual history. At this starting-point geometry is not yet capable of being handed on: it has not yet attained the stage of "ideal objectivity," as a condition of its becoming the common property of many individuals. At least three steps are required in order to reach this stage. To begin with, the original evidence, experienced during the first actual production, passes over into a "retentional" consciousness and finally fades away into forgetfulness. But it does not disappear completely: it can be awakened, and the "active" remembrance of the original production of any ideal significant formation car-

30. P. 209.
31. Cf. *Logik*, p. 278.
32. "Geometrie," *loc. cit.*, p. 208.

ries with it the evident experience of the sameness of that formation, carries furthermore the insight into its unlimited reproducibility. This experience does not, however, transcend the personal sphere of the subject. The second necessary—and decisive—step is the embodiment of that experience in words, which makes it communicable to other subjects: these others are thereby enabled to reproduce the same evident experience out of their own mental activity. The "ideal significant unit" acquires its peculiar manner of existence only through speech and in speech. A last step remains to be taken in order to secure the *lasting* existence of the "ideal objects," to establish their perfect "objectivity." It is the translation of the spoken word into the written word. At this stage the real history of a science may begin. It is, of necessity, not only the history of "progress," of the accumulation of knowledge, but also a history of failure. The means which secure the objectivity of a science at the same time endanger its original integrity. No science, in its actual progress, can escape the "seduction" emanating from the spoken and written word. For the signifying function of a word has, by its very nature, the tendency to lose its revealing character. The more we become accustomed to words, the less we perceive their original and precise "significance": a kind of superficial and "passive" understanding is the necessary result of the increasing familiarity with spoken and written words. The original mental activity, the production of significance, embodied in sounds and signs, is not reproduced in the course of actual communication. Yet it is there, in every word, somehow "forgotten" but still at the bottom of our speaking and our understanding, however vague the meaning conveyed by our speech might be. The original "evidence" has faded away but has not disappeared completely. It need not be "awakened" even; it actually underlies our mutual understanding in a "sedimented" form. "Sedimentation is always somehow forgetfulness."[33] And this kind of forgetfulness accompanies, of necessity, the development and growth of a science.

To be sure, the original evidence can be "reactivated," and actually is at definite times, in order to restore the full

33. P. 212.

significance of all the previous steps leading to a given stage within the development of a science. This interlacement of original production and "sedimentation" of significance constitutes the true character of history.[34] From that point of view there is only *one* legitimate form of history: the history of human thought. And the main problem of any historical research is precisely the disentanglement of all these strata of "sedimentation," with the ultimate goal of reactivating the "original foundations," i.e., of descending to the true beginnings, to the "roots," of any science and, consequently, of all prescientific conceptions of mankind as well.[35] Moreover, a history of this kind is the only legitimate form of epistemology. The generally accepted opposition between epistemology and history, between epistemological and historical origin, is untrue. More exactly, the problem of history cannot be restricted to the finding out of "facts" and of their connection.[36] They embrace all stages of the "intentional history." History, in this understanding, cannot be separated from philosophy.

Reactivation of the "sedimented history" may become the most imperative need in a given situation. The "sedimentation of significance" can reach such a degree that a particular science, and science in general, appear almost devoid of "significance." This has been becoming increasingly the state of affairs in recent centuries and is the case now.[37] Husserl deals explicitly with this unique situation in his "Crisis of the European Sciences." We shall confine our considerations of this matter to the special problem of mathematical symbolism as the main instrument *and* the real basis of mathematical physics.

IV

Husserl's philosophy, as it appears in its latest phase, is an admirable attempt to restore the integrity of knowledge, of ἐπιστήμη, threatened by the all-pervading tendency of "sedimentation." His analysis of the meaning of "tradition" and "historical

34. P. 220.
35. Pp. 212, 218 f.
36. Pp. 220 f.
37. P. 217.

development" is directly motivated by this purpose. The increase of "sedimentation" follows closely the establishment of the new science of nature, as conceived by Galileo and Descartes. Or rather, the new science itself, with all its amazing accomplishments and far-reaching potentialities, is basically the product of an accumulated sedimentation, the reactivation of which is usually not conceived as a possible or even desirable task. As Husserl puts it: "Galileo, the discoverer . . . of physics and of the corresponding kind of nature, is both a revealing and a concealing genius."[38] In analyzing the foundations of Galileo's physics, Husserl does not intend to give a detailed historical account. Galileo's name is, in this connection, somewhat of a collective noun, covering a vast and complex historical situation.[39] On the other hand, this analysis is intended to shed light on the origin of modern consciousness in its universal aspect.[40] The problem of the origin of mathematical physics is the crucial problem of modern history and modern thought.

We shall not follow Husserl's pattern here, but try to give a general outline of that actual historical development, referring, in due course, to Husserl's corresponding statements. It should be emphasized that Husserl's "intentional-historical" analysis of the origin of mathematical physics, although not based upon actual historical research, is on the whole an amazing piece of historical "empathy."

The establishment of modern physics is founded upon a radical reinterpretation of ancient mathematics,[41] handed on through the centuries and acquiring a new dignity in the middle of the sixteenth century. The *Elements* of Euclid are subjected to careful studies, are commented upon and continuously re-edited and reprinted. The "Euclidean spirit" spreads rapidly. Archimedes and Apollonius, newly rediscovered, are studied but are understood by relatively few. On the other hand, the discovery of manuscripts of Diophantus helps to transform the Arabic art of algebra—a dark art, comparable to alchemy—into a science accepted as a supplement to the traditional

38. "Krisis," p. 128.
39. Cf. p. 133.
40. P. 132.
41. Cf. p. 95.

quadrivium of the mathematical disciplines. The publication and translation of Proclus' commentary on the first book of Euclid allows a fusion of the traditional theory of ratios and proportions with the "algebraic" *art* of equations. The importance of this book by Proclus cannot be overestimated. The algebra (leading back, at least partly, to a Greek tradition represented by Diophantus and Anatolius) and especially the *Arithmetic* of Diophantus are understood as an immediate application of the theory of ratios and proportions. Moreover, the (Eudoxean) "general" theory of proportions, as laid down in the fifth book of Euclid, seems to indicate that the "vulgar" algebra as well as the *Arithmetic* of Diophantus is but a remnant of a more general theory of equations, of a *true* and more general algebra. It is Vieta who works out the logical and mathematical consequences of this insight and becomes thus the "inventor" of modern mathematics. Let us consider briefly the way in which he proceeds.

The method of Diophantus consists in setting up an indeterminate equation which is immediately converted into a determinate one by the arbitrary assumption of a numerical value. This equation has a purely numerical character: apart from the unknown quantity, the "given" quantities as well as the coefficients of the unknown are definite numbers. Having solved an equation by methods which are often very ingenious, Diophantus refers in not a few cases to the easily performed checking of the result in these terms: καὶ ἡ ἀπόδειξις φανερά (and the demonstration [the "proof"] is obvious). Now, a "demonstration" in Greek mathematics means the "synthesis" which is the reverse of the preceding "analysis." Therefore Vieta calls the Diophantean solution an "analytical" process, referring himself to the traditional definition of analysis as the "way from the unknown taken as a known, through the consequences, down to something which is known."[42] This Greek definition applies, however, to the geometrical analysis, which in its procedure does not make use of any definite magnitudes, comparable to the definite numerical values of a Diophantean equation. Assuming that the "general" method behind the "Diophantean analysis" must be

42. Pappus, ed. Hultsch, II 634. Cf. the scholium to Euclid xiii, prop. 1-5.

applicable to the numerical *as well as to the geometrical procedure*, Vieta postulates a reckoning (*logistice*, λογιστική) using not number but merely "species" (taking over the Diophantean term "species," εἶδος, applied by Diophantus to the various powers of the unknown). Thus he opposes a "restored" and "pure" algebra, the *logistice speciosa*, to the commonly used Diophantean *logistice numerosa*.[43] At the same time, this pure algebra represents, in his mind, the general theory of proportions. Described by Proclus as the "highest" mathematical discipline, the general theory of proportions in the form of Vieta's pure algebra becomes from now on the fundamental discipline not only of mathematics but of the system of human knowledge in general.[44] The translator of Proclus into Latin, Barocius, in order to designate this highest mathematical discipline, uses the term *mathesis universalis*, referring to it on the margin as *scientia divina*. It is from this source that Descartes,[45] and the entire seventeenth century, have derived the term and the conception of a "universal science" which includes all possible sciences of man.

This universal science bears from the outset a *symbolic* character.[46] In creating his *ars analytice*, Vieta introduced for the first time, fully conscious of what he was doing, the notion of a mathematical *symbol* and the rules governing symbolic operations: he was the creator of the mathematical *formula*.[47] In doing this, he preserved, however, the original "ideal" concept of number, developed by the Greeks out of the immediate experience of "things" and their prescientific articulation. In Vieta's notion of "species" the original understanding of number is retained, as it is, of course, in the *Arithmetic* of Diophantus. But his immediate successors, Ghetaldi, Harriot, Oughtred, and Wallis (partly under the influence of Stevin and, as far as Wallis is concerned, of Descartes' *Geometry*), have already lost the original intuition. The technique of operating with symbols replaces the science of numbers.[48] Descartes, for his part, aiming at the all-comprehensive *mathesis universalis*, and follow-

43. Cf. "Krisis," p. 97.
44. Cf. pp. 120 ff.
45. Cf. *Regulae*, Reg. iv.
46. Cf. "Krisis," pp. 119, 123.
47. Cf. pp. 115 f., 118, 123.
48. Cf. p. 123.

ing the algebraic doctrine of Stevin, transforms the traditional understanding of Euclidean geometry into a symbolic one, which transformation is at the basis of his analytic geometry.[49] His mathematical significance lies in the fact that he subjects the traditional geometry to the same kind of symbolic "formalization" to which Vieta subjected the Diophantean arithmetic.

This establishment of a fundamental analytical discipline, planned in advance by Vieta as well as by Descartes for the sake of founding a "true" astronomy and a "true" physics, inaugurates the development of a symbolic science of nature, commonly known as mathematical physics.[50] As to Galileo, he has not yet at his disposal the powerful instrument of symbolic formulae. His physics is conceived as an application of Euclid's (and Archimedes') geometry,[51] especially of the Euclidean theory of proportions. But he is already under the spell of that general symbolic tendency: he anticipates mathematical physics in his concept of an "exact" nature as a great book written in mathematical characters. The implications of this concept of an "exact" nature are unfolded in this work and in the work of the following generations. But the "sedimented significance" upon which this work and the concept of an exact nature itself rest, have hardly been "stirred up," or even touched, ever since Galileo, Kepler, and Descartes laid the foundations of mathematical physics.[52] The "intentional history," as suggested by Husserl, may accomplish this task: it may "reactivate" the "sedimented" "evidences," may bring to light the forgotten origins of our science. A history of science which fails to tackle this task does not live up to its own purpose, however valuable and indispensable it otherwise might be.

The problem of the origin of modern science thus presents a threefold aspect. There is first the "anticipation" of an exact nature, implying the possibility of reducing *all* appearances to geometrical entities. Not only the "prominent" features men-

49. The analytic geometry itself is, as an algebraic geometry, a "formalization" of the methods used by Apollonius. This holds for the analytic geometry of Fermat as well. Both, however, considered the analytic geometry as an expansion, a "generalization," of the procedure of Apollonius, not as a "new" discovery.
50. Cf. "Krisis," p. 97.
51. Cf. pp. 98 ff., 102 ff., 113.
52. Cf. p. 117.

tioned above (i.e., some of the so-called primary qualities), with their essentially geometrical characteristics, but also the so-called secondary qualities, such as color, sound, odor, warmth (i.e., the "specific" sensory qualities)[53] as well as change and motion, are understood to be convertible either into geometrical magnitudes or at least into something that can be treated geometrically, having definite ratios and proportions. This kind of approach to all possible qualities of things can be traced back to the nominalistic school of the fourteenth century, especially to Nicolaus Oresmus (Nicole Oresme), whose work *De uniformitate et difformitate intensionum*[54] has profoundly influenced all following thinkers up to Galileo, Beeckman, and Descartes.[55] The "sedimentation" involved in this "Euclidean" approach to the world consists in the matter-of-course attitude toward geometrical evidence.[56] Accordingly, our *first* task is the intentional-historical reactivation of the origin of geometry.

In trying to fulfill the anticipated conversion of *all* "natural" appearances into geometrical entities, in trying to geometrize nature, the physicist faces immediately the problem of finding the adequate means for such an undertaking. This problem is solved through what can be called the method of *symbolic abstraction*, which is quite different from the ancient ἀφαίρεσις. It is the method used consciously by Vieta in his establishment of a "general" algebra and by Descartes in his early attempt to set up the *mathesis universalis*.[57] It amounts to a symbolic understanding of magnitudes *and* numbers, the result of which is an algebraic interpretation of geometry. The roots of this development can be found in the adoption of the Arabic system of numeration which leads to a kind of indirect understanding of numbers and ultimately to the substitution of the ideal numerical entities, as intended in all Greek arithmetic, by their symbolic expressions. That is to say, a "sedimented" understand-

53. Cf. pp. 104, 108.
54. The same work is also known under the significant titles: "De figuracione potentiarum et mensurarum difformitatum," and "De configuracionibus qualitatum."
55. Cf. P. Duhem, *Études sur Léonard de Vinci*, vol. iii (1913); and also the correspondence between Beeckman and Descartes in *Oeuvres de Descartes* (ed. Adam Tannery), vol. x, and Descartes' *Regulae*, Reg. xii.
56. Cf. "Krisis," p. 111.
57. Cf. Descartes, *Regulae*, Reg. xiv.

ing of numbers is superposed upon the first stratum of "sedimented" geometrical "evidences." This complicated network of sedimented significances underlies the "arithmetical" understanding of geometry.[58] The second task involved in the reactivation of the origin of mathematical physics is, therefore, a reactivation of the process of symbolic abstraction and, by implication, the rediscovery of the original arithmetical evidences.

Upon those combined "sediments" reposes finally our actual interpretation of the world, as expressed not only in our science but also in our daily life.[59] In fact, the "scientific" attitude permeates all our thoughts and habits, no matter how uninformed or misinformed about scientific topics we may be. We take for granted that there is a "true world" as revealed through the combined efforts of the scientists, whatever doubts the scientists themselves may have on the subject. This idea of a true, mathematically shaped world behind the "sensible" world, as a complex of mere appearances, determines also the scope of modern philosophy. We take the appearances of things as a kind of disguise concealing their true mathematical nature. But we have "forgotten" that this nature, "anticipated" by the founders of modern science, was to be *constructed*[60] by means of ingenious methods, that the original *hypothesis* of an "exact" nature had to prove true, without ever being able to lose its character as a hypothesis.[61] The "anticipation" of an exact nature is the anticipation of its history. Its history is the development of the method of symbolic abstraction. It takes the form of an *art*, consisting in the continuously perfected technique of operating with symbols.[62] The "exact" nature is not something that is concealed behind the appearances, but rather a symbolic disguise concealing the original "evidence" and the original experience of things.[63] Hence a *third* task arising from the attempt to reactivate the "sedimented history" of the "exact" nature: it is the rediscovery of the prescientific world and its true origins.[64]

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58. Cf. "Krisis," p. 119.
59. Cf. p. 124.
60. Cf. p. 107.
61. Cf. pp. 113, 114, 115, 116 f.
62. Cf. pp. 115, 121.
63. Cf. p. 126.
64. Cf. pp. 124 ff., 132.